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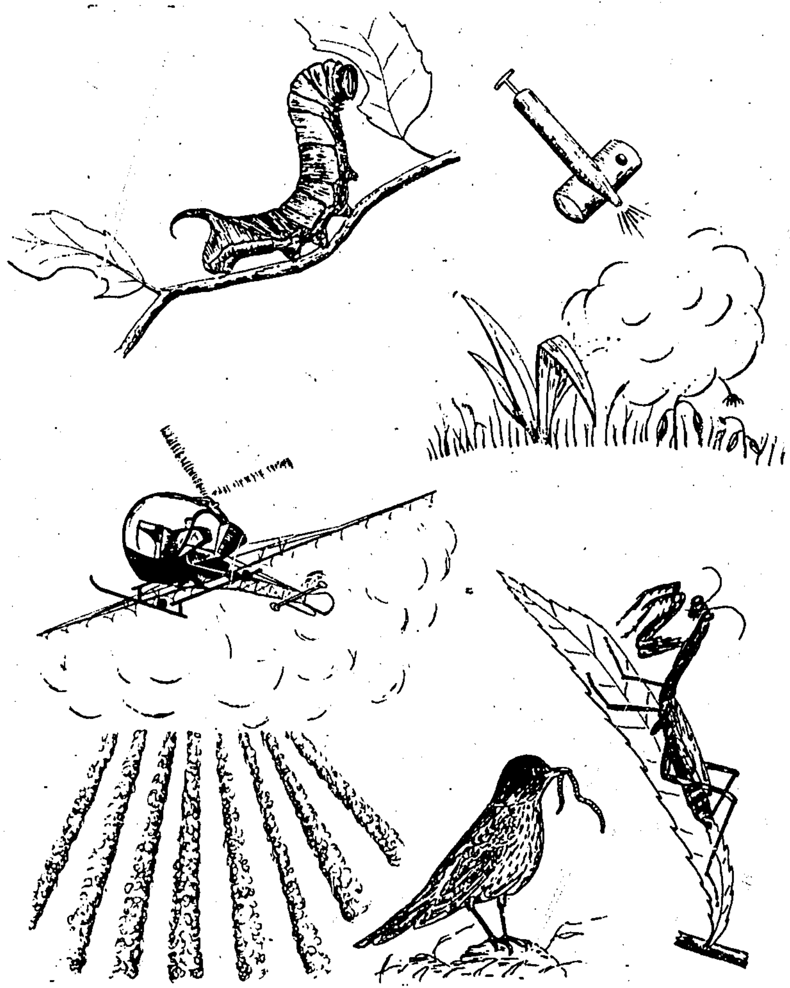
ABSTRACT

Consideration of the dangers of pesticides to the world ecosystem as well as the economic necessity which an affluent society has created are the two sides of the pesticide problem discussed in this issue. An attempt is made to clarify the issue, to recognize the ways that pesticides exert their effects, and to relate what measures can be taken to provide a safe environment for future generations. Specific topics study the history of pesticide development and use, economic values (benefits to man), chemicals for pest control categorized as to origin or chemical structure, presence of pesticides in the environment, physiological and biochemical effects, new approaches to pest control, the future of pesticides, and suggestions for the home gardener. Several diagrams, charts, and tables help to clarify the information. A product list and references are also given. (BL)

PESTICIDES And The ENVIRONMENT



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PESTICIDES And The ENVIRONMENT

GAYLEN NEUFELD

The usage of pesticides is an emotional issue which has generated bitter controversy particularly in the last decade and beginning with the publication of Silent Spring by Rachel Carson. Some contend that the use of pesticides provides the only way to meet the food needs of an increasing population and to allow the agriculturist to remain economically viable. On the other hand, many see pesticides as an agent of destruction which is leading to the extinction of wildlife and may in time have a similar effect upon humans. Unfortunately, many of the arguments made for or against pesticides are made out of ignornace. A rational approach needs to be followed which takes into consideration the dangers of pesticides to the world ecosystem as well as the economic necessity which an affluent society has created. This issue of The Kansas School Naturalist will discuss some of the aspects of the pesticide problem. Hopefully this will help clarify the issue and allow the reader to recognize the ways that pesticides exert their effects and what measures can be taken to provide a safe environment for future generations.

This issue of The Kansas School Naturalist was written by Dr. Gaylen Neufeld, Associate Professor of Biology at KSTC. He is a cellular physiologist with a research interest in pesticide biochemistry and physiology. Illustrations by Robert Boles.

The Cover: Man is faced with a dilemma when confronted by crop-destroying insects, competing plants called "weeds" and other pests. The use of pesticides provides a way to deal with this competition but they may also affect organisms which are beneficial such as the robin, earthworm, praying mantid, ladybug beetle and many others.

History of Development and Use

Extensive use of chemicals against insect pests began less than 100 years ago with the use of arsenic-containing mixtures against the Colorado potato beetle. Crude chemicals were used for insect control long before this however. Such uses were local and sporadic and the concoctions were often applied in desperation. The major insecticidal use of arsenic in insect control was begun as the sulfide in the late 1500's. Subsequent but still early uses of insecticides consisted largely of arsenical baits for ants, grasshoppers and snails, tobacco plant preparations for aphid and lace bug control, powdered pyrethrum flowers for household insects and sulfur as a dust or fumigant for preservation of stored products.

Early modern insecticides were largely inorganic in nature and contained compounds of antimony, arsenic, mercury, selenium, sulfur, thallium and zinc as active ingredients. These compounds are effective insecticides with long residual action. They affect chewing insects only but may also accumulate in soils to the point where they become toxic to plants.

Contact insecticides date back into ancient Chinese history when certain plant extracts were used. About 300 years ago crude tobacco preparations were used for control of a lace bug on pear trees in France. The active component in these preparations was nicotine which is quite effective and is still widely used as the active ingredient in certain commercial preparations.

Fumigants to rid homes and commodities of annoying pests were known to ancients. Homer in the Odyssey mentions the use of sulfur fumes. Hippocrates refers to the use of fumigation by burning various gums and resins.

Modern insecticide use did not flourish until the late 1930's and early 1940's. The Second World War stimulated research on an unprecedented scale and led to a new category of pesticides, the synthetic organic compounds. DDT was introduced in about 1942 and was used with spectacular success against fleas, flies, lice, mosquitos and ticks. The U.S. Army was the major user in its fight to protect the soldier from the ravages of malaria, typhus and other insect-borne diseases. This compound was first developed by Othmar Zeidler, a young chemistry student at Strasbourg, Germany in 1874. However, its insecticidal qualities remained unknown for about sixty years. Then in 1934, Dr. Paul Müller, who was unaware of the earlier work of Zeidler, synthesized DDT in Switzerland and discovered its potential as an insecticide. Its first major use saved the potato crop of Switzerland from the Colorado potato beetle.

Organophosphorus compounds were introduced into world-wide use in 1946. These are highly effective chemicals with short residual activity which are used extensively today.

Despite the widespread acceptance and use of modern insecticides, there are three factors which may actually accentuate the insect problem. These are as follows:

1. Insect introductions through travel and commerce.
2. Upsets of balances of nature.
3. Development of insect resistance to many insecticides.

Economic Value

History abounds with accounts of sufferings and deprivations visited upon human populations by competing hordes of pests. Present living standards and practices dictate that many forms of pesticides must be used in the control of pests. Benefits to man fall generally into four categories.

1. **Preservation of materials.** The use of mothballs to protect woolen materials from damage has been a common practice. The use of such chemicals may have decreased however with the move toward synthetics. Many products available to the consumer contains materials that minimize the damage inflicted by various organisms. Housepaints, for example, now usually contains an anti-fungal component to control the growth of mold. Termites annually cost homeowners many dollars in wood damage. Chemicals are used extensively to control these pests.

2. **Control of nuisance-type insects.** Everyone has probably at one time or another purchased an aerosol can of insect repellent that allows us to enjoy a picnic without contending with annoying flies and mosquitos. Many insects do not endanger our health or compete for food directly but simply become unpleasant companions in our leisure pursuits.

3. **Agricultural uses.** Man has competed for centuries with insects and weeds in his effort to produce food for hungry mouths and empty stomachs. He purposefully contaminates his environment with pesticides to tilt the cost-benefit ratio in favor of the farmer and ultimately the consumer of agricultural products. They are a major reason why the U.S. farmer feeds and clothes 46 persons today. This is compared with 25 persons in 1960 and only 4 persons in 1850. Pesticides often represent the slender margin between economic profit and economic loss.

Modern agricultural technology depends upon the use of a variety of pesticides for treatment of soil and seeds, weed control, protection of crops from diseases and insects and post-harvest preservation of agricultural products.

4. **Control of insect disease vectors.** The use of pesticides has dramatically reduced sickness and death due to disease-carrying insects. Humans are susceptible to a wide variety of diseases spread by insects and have suffered incredibly over the centuries. The use of pesticides is one of several reasons why the death rate world-wide had dropped dramatically. A partial listing of arthropod-borne diseases is given in Table 1.

Chemicals for Pest Control

Chemicals that are used for the control of pests vary widely as to type and origin. They may be categorized by the type of pest controlled, for example, fungicides, herbicides, insecticides, rodenticides, etc. Another listing categorizes them as to origin or chemical structure.

Table 1. Representative list of arthropod-borne diseases.

Disease	Vector	Animal Affected
African sleeping sickness	Tsetse flies	Man, domestic animals
Anthrax	Horse flies	All mammals
Bubonic plague	A rat flea	Man, rodents
Epidemic typhus	The human louse	Man
Filariasis	Several mosquitos	Man
Malaria	Anopheles mosquito	Man, birds
Q fever	Ticks	Man
Relapsing fevers	Several ticks	Man, rodents, fowl
Rocky Mountain spotted fever	Two ticks	Man, rodents
Yellow fever	Several mosquitos	Man, many animals
Encephalitides	Several mosquitos	Man, horse, bird

1. **Pesticides of Natural Origin.** The use of tobacco as an insecticide dates back several centuries. The active component is nicotine which affects the nervous system of insects. Another natural chemical is rotenone, a compound found in the roots of certain legumes. They both have low mammalian toxicity and are still used to some extent in home gardens and powders for keeping small animals free of fleas and other ectoparasites.

Ryania is a mixture of substances from the stems and roots of Ryania speciosa, a shrub of tropical South America. It is highly toxic to some insects, particularly caterpillars and has been used successfully for the control of the European corn borer and codling moth.

Extracts of the dried flowers of certain chrysanthemum plants contain pyrethrum which has insecticidal qualities. This was well known in Persia and the Caucasus in the middle 19th century. Many of the present commercial pesticides contain pyrethrum as the active component.

2. **Inorganic compounds.** The first synthetic insecticides were inorganic. One of the first to be used successfully was Paris green in 1867 for the control of the Colorado potato beetle. This is a copper and arsenic compound which is generally toxic to leaf-eating insects. Lead arsenate is highly effective but because of its toxicity to humans, it has never been popular among safety authorities. Sodium fluoride and related compounds are particularly effective against gregarious crawling insects.

3. **Chlorinated hydrocarbons.** The most notable chemical in this category is DDT. These compounds are characterized by their high toxicity and long residual action. Most of the attention surrounding the pesticide controversy has centered upon chemicals in this category. Others in this group include methoxychlor, lindane, chlordane, heptachlor, dieldrin, endrin and aldrin.

4. **Organophosphates.** Compounds of this category tend to be extremely toxic to a wide range of organisms, including humans. They do, however, break down rapidly in the environment and hence have little residual action. All of these compounds inhibit certain enzymes in the living organism, particularly cholinesterase which breaks down acetylcholine, the chemical responsible for the transmission of the impulse from the nerve to the muscle. In the absence of cholinesterase, the acetylcholine accumulates and interferes with the coordination of muscular response. Such interference in the muscles of vital organs produces convulsions and eventually death. Members of this group include parathion, malathion, diazinon and others. Parathion has probably caused more deaths than all other modern pesticides. Organophosphates are absorbed through the skin as well as through the respiratory and gastrointestinal tracts.

5. **Carbamates.** This is a group of chemicals which has been widely advertised as being relatively safe and effective. It includes Sevin and Zectran which are broad spectrum, general purpose insecticides.

6. **Herbicides.** The parent compound for many of the chemicals in this group is phenoxyacetic acid. Certain of these compounds have growth-regulating properties and can be used in selective weed control. The best known of these is 2,4-D and 2,4,5-T. They are cheap and selective for broad-leaves so that cereal plants are not affected.

Many other types have been synthesized which are also highly effective and selective.

7. **Others.** A host of other chemicals have been discovered which are useful in the control of fungi, rodents, plant parasites, and mites and ticks.

Presence in the Environment

Since the time that pesticides have been extensively used, an enormous amount has been introduced into the world's ecosystem. It should be emphasized that for the most part, these chemicals are new to the biosphere and hence there has been little time for natural systems to develop degradative enzymes that remove them. Therefore, many of these chemicals tend to remain for many years before the levels return to pre-application values. The accompanying figure (Fig. 1) illustrates the total sales of fungicides, herbicides and instecticides in the United States for the period 1962-69. The U.S. Department of Agriculture in 1966 estimated that of 350 million acres of land cultivated, herbicides were applied to 27%, insecticides to 12% and fungicides to 2.6%. However the rate of application is much higher in intensively farmed areas.

The use of pesticides has become virtually indispensable to modern agriculture. Yet for the majority of the chemicals, we only have superficial knowledge concerning the effects of long-term use in the environment. A veritable mountain of data has been accumulated concerning the contamination of animals, crops, soil, foods and even humans. In relation to the total problem however, inquiry needs to be made concerning rates of accumulation in soils and water, effects on soil microflora, the effects upon food chains and the possibility that some of the compounds may in fact be mutagenic, teratogenic or carcinogenic in humans.

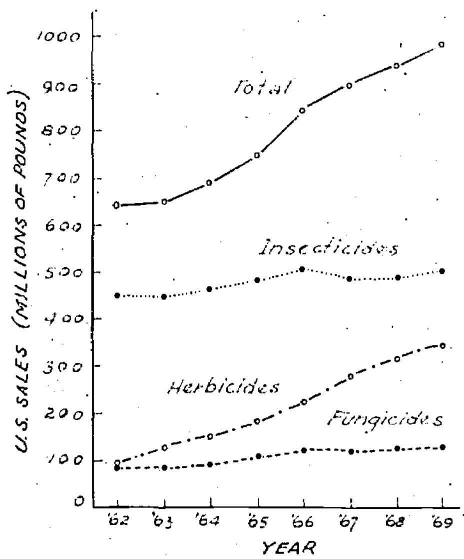

Fig. 1.

Sales of pesticides in the United States, 1962-69. (Modified from: Metcalf, Robert L. 1971. Pesticides. Journal of Soil & Water Conservation. March-April, pp. 57-60.).

Since most of the controversy concerning pesticides has been centered around the chlorinated hydrocarbons and in particular DDT, much of the remaining discussion will deal with this group of chemicals.

Residues of these chemicals have sometimes been found in organisms, soil, and even ice thousands of miles from the point of application. A basic comprehension of the physical properties of these chemicals (chlorinated hydrocarbons or organochlorines) will enable the reader to better understand some of the effects upon the ecosystem.

1. These compounds are said to be persistent in that they are stable and remain in toxic form long enough to contaminate non-target organisms, often many miles from the site of use.

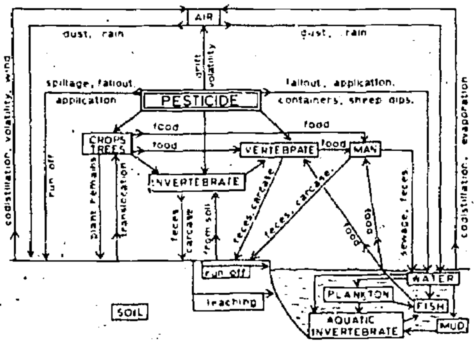

Fig. 2.

Pesticide cycling in the environment. (From: Edwards, Clive A. 1970. Persistent Pesticides in the Environment. The Chemical Rubber Co.).

2. These compounds are mobile. They may form suspensions in air and water or adsorb to particulate matter present in air and water. Furthermore the vapor pressure is such that they codistil with water and may escape from wet soil through evaporation of moisture. They may thus circle the globe and come down in the precipitation elsewhere.

3. They have a broad spectrum of biological activity. The effects may extend to many non-target organisms.

4. These chemicals have a low solubility in water and high solubility in lipid material. Biological membranes contain large quantities of lipid compounds. Pesticides are thus easily taken up by living organisms.

The cycling of pesticides in the environment is illustrated in figure 2. The movement through the various compartments of the environment precludes their remaining a local problem. Tests in Maine and New Brunswick have shown that DDT sprayed from airplanes to control the spruce budworm in forests did not all necessarily end up at the site of application. Even in the open, away from trees, only about one-half of the DDT reached the ground. The rest was presumably dispersed as crystals in the air.

One of the greatest concerns of biologists is the effects of these persistent pesticides as they accumulate in greater amounts at the higher trophic levels in food chains. Energy flow in an ecosystem is illustrated by the food web shown in figure 3. Analysis by scientists in New York have shown the complexity of this particular ecosystem. It is evident that most of the consumers feed on several different organisms. In other words, the food chains are interlinked. Complexity is believed to be in part responsible for the stability of an ecosystem. The more crosslinks there are, the more chances there are for the ecosystem to compensate for stresses imposed upon it. The cross-connecting links also mean that any toxic substances entering the web is distributed across it. The accumulation at higher trophic levels in a food chain as shown by the numbers is referred to as biological magnification. Figure 4 illustrates how this occurs. As biomass or living material is transferred from one level to another usually more than half is lost in respiration or by excretion. The remainder forms new biomass in the next trophic level. Losses of DDT residues in this

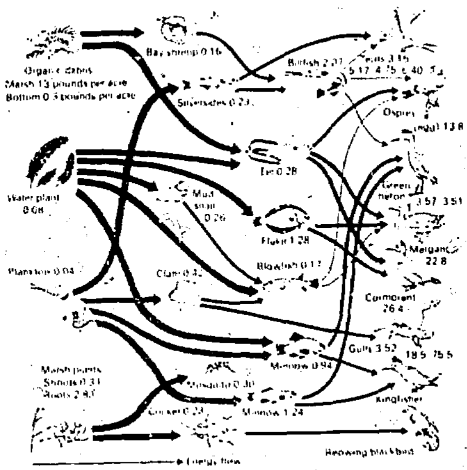

Fig. 3.

Food web in a Long Island estuary. Numbers indicate parts per million of DDT and its derivatives on a wet weight, whole-body basis. Arrows represent energy flow. (From: Woodwell, George M. 1967. Toxic Substances and Ecological Cycles. Scientific American, March, p. 24).

case, are not proportional to the loss of biomass. For this reason higher concentrations are found in the carnivores.

Other ecosystems have been analyzed and similar results are found. Lake Michigan, for instance, contains DDT in the water at about 2 ppt (parts per trillion). Bottom samples, however, contain an average of 0.014 ppm (parts per million), amphipods, 0.41 ppm; fish 3-6 ppm; and herring gulls at top of the food chain, as much as 99 ppm. This represents an approximate five million-fold concentration from the water.

The environmental toxicity of mercury is well documented. The initial evidence for this came from the tragedy at Minamata Bay, Japan. Fish and other marine orgnisms represents a large portion of the diet for the inhabitants of this area. In the period 1953-60, 111 persons were reportedly poisoned with 44 deaths after eating fish loaded with mercury discharged by industries on the shores of the bay. Mercury poisoning is now often referred to as Minamata disease. In 1970, it was found that there was considerable mercury pollution in Lake Erie. Fish from this lake contained mercury at levels up to 3.5 ppm, well in excess of Federal Drug Administration safety-standards. Wild game in the western part of the United States and Canada have been shown to be contaminated with mercury. Wild game in Sweden presented the first warning that industrial discharges of mercury was contaminating their envirnoment. Prompt action by the Swedish government brought restrictions on the uses of mercurials.

Microbial metabolism of mercury yields methyl mercury which is volatile and lipid soluble. This provides a mechanism for the circulation in the environment and accumulation by living organisms.

Analysis of various organisms shows that there is widespread contamination by DDT and other persistent pesticides. Data such as this correlates closely with the increased usage over the years. Furthermore, organisms far from areas of usage contain appreciable quantities indicating again the transport through the biosphere. Innumerable studies show that this contamination affects virtually

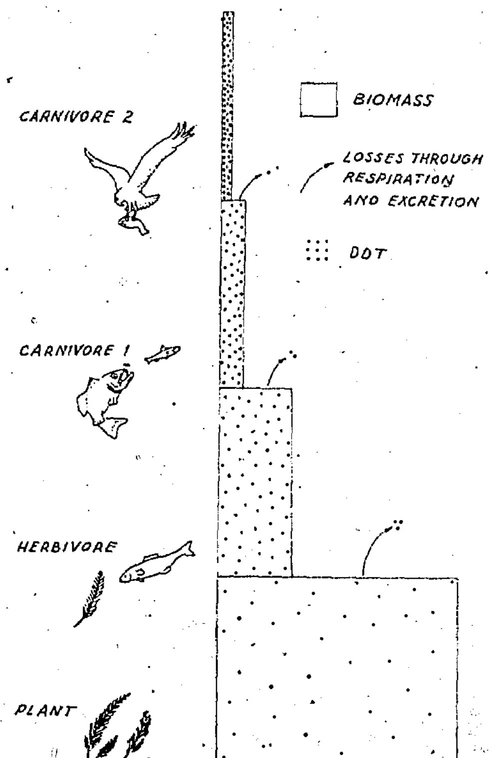

Fig. 4.

Transport and concentration of DDT along a simple food chain to illustrate concept of "biological magnification." (From: Woodwell, George M. 1967. Toxic Substances and Ecological Cycles. Scientific American. March, p. 24).

all organisms including humans (Table 2). It has been shown that pesticides in humans crosses the placental barrier and thus the fetus becomes exposed as well. Human milk in certain areas of the world reportedly contains pesticide residues and would be declared unfit for human consumption if it were cows' milk.

A great deal of concern has been expressed for particularly the birds of prey that occupy the top of food chains. The greatest danger for these animals is that chlorinated hydrocarbons alters their metabolism in such a way that reduces the amount of calcium in the shell of

Table 2. Concentration of DDT residues and its derivatives in various living organisms. (From: Woodwell. George M. 1967. Toxic Substances and Ecological Cycles. Scientific American. March, p. 24).

Location	Organism	Tissue	Concentration (parts per million)
U.S. (average)	Man	Fat	11
Alaska (Eskimo)			2.8
England			2.2
West Germany			2.3
France			5.2
Canada			5.3
Hungary			12.4
Israel			19.2
India			12.8-31.0
U.S.			
California	Plankton		5.3
California	Bass	Edible Flesh	4-138
California	Grebes	Visceral Fat	Up to 1,600
Montana	Robin	Whole Body	6.8-13.9
Wisconsin	Crustacea		0.41
Wisconsin	Chub	Whole Body	4.52
Wisconsin	Gull	Brain	20.8
Missouri	Bald Eagle	Eggs	1.1-5.6
Connecticut	Osprey	Eggs	6.5
Florida	Dolphin	Blubber	About 220
Canada	Woodcock	Whole Body	1.7
Antarctica	Penguin	Fat	0.015-0.18
Antarctica	Seal	Fat	0.042-0.12
Scotland	Eagle	Eggs	1.18
New Zealand	Trout	Whole Body	0.6-0.8

the egg. With the reduction of this vital element, the eggshell is thinner and more fragile. Breakage of eggs during incubation is extensive and reproductive success is thus decreased. There have been dramatic decreases in the hatches of many birds and hence a population decrease results.

One of the things to be considered when a pesticide is to be used is the effect it might have upon the balance that exists between different organisms of the habitat. A reduction in population or activity of beneficial predators can lead to an enormous increase in a pest problem. Such an upset in the equilibrium may occur when the beneficial predators are more affected by the pesticide than the pests themselves. Such a situation is illustrated in figure 5. This represents a test plot containing predatory mites and their prey, the springtail. Organophosphorus insecticide was used in the test. The predatory species suffered immediately while the springtail population was scarcely affected. In fact, there was an increase in numbers due to the reduction of predators.

A computer model of DDT flow in the environment shows that the problem may exist

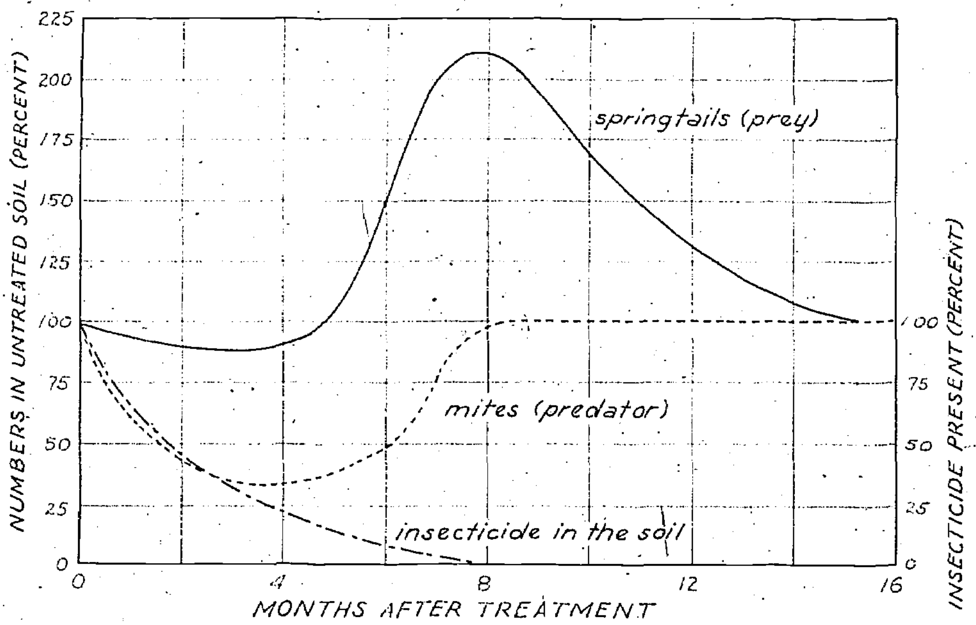

Fig. 5.

Effect of organophosphate insecticide on predatory-prey balance in a test plot. (From: Edwards, Clive A. 1969. Soil Pollutants and Soil Animals. Scientific American. April, p. 88).

even after the usage has been halted (Fig. 6). The graph illustrates what would happen if in 1970 the world DDT application reached its peak and thereafter decreased until finally it reached zero usage in the year 2000. Because of the inherent delays in the system, made possible by the persistence of the chemical and the flow through different compartments of the environment, the level in fish continues to rise for approximately 11 years after the application of DDT has begun to decline. Furthermore, the level in fish does not reach 1970 levels until more than two decades later.

It should be noted here that the United States has banned the use of DDT effective December 31, 1972. Public health and quarantine considerations, a few minor crop uses, and export are exceptions.

Ecosystem modeling of DDT movement in the biosphere by scientists at Brookhaven National Laboratory in New York suggest that the residues flow from the land through the atmosphere into the oceans and finally into the oceanic abyss. The model further suggests that the maximum concentration in the air may have occurred in 1966 and in the mixed layers of the ocean in 1971.

Physiological and Biochemical Effects

It has been said that people understand acute poisoning but they find subtle physiological changes difficult to grasp. A great deal is known about the accumulation, concentration and toxicity of pesticides but relatively little is known concerning its metabolic effects. Probably more is known about the eggshell-thinning phenomenon in birds than any of the other biochemical effects. The chlorinated hydrocarbons induce a thinning of the eggshell in a variety of birds, including the brown pelican, bald and golden eagle, black ducks, mallard, Alaskan falcons and hawks, Japanese quail, ringdoves, Western grebe, osprey, peregrine falcon, sparrow hawk, Bermuda petrel and Herring gulls. On the other hand, chlorinated hydrocarbons do not seem to affect eggshell thickness in the domestic chicken. Related chemicals, the polychlorinated

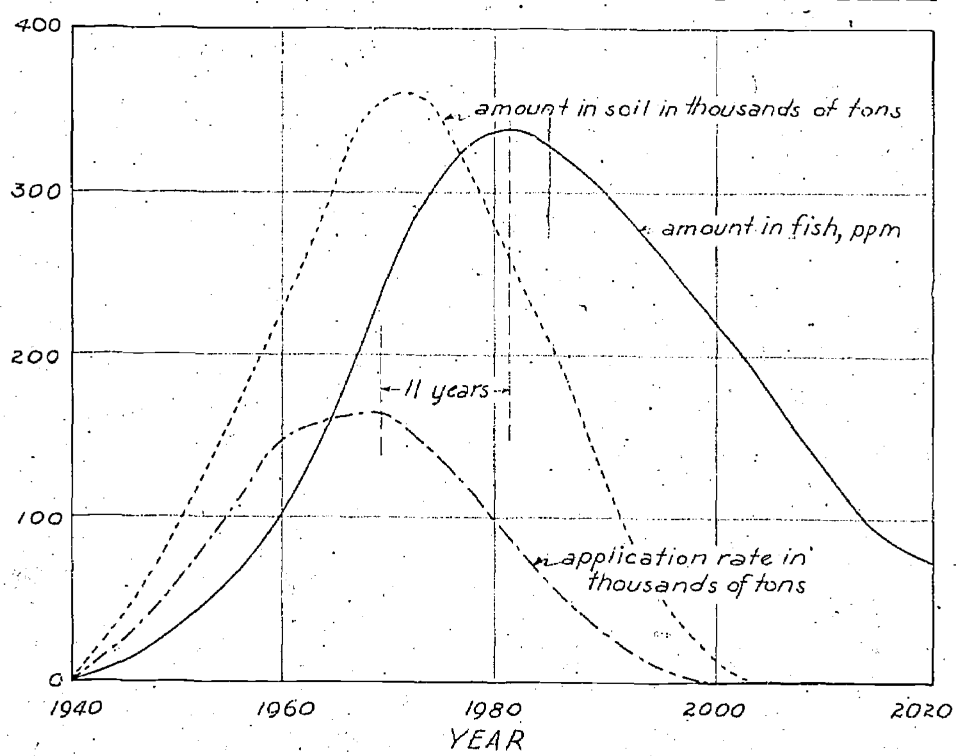

Fig. 6.
Computer calculation of DDT in the environment. DDT application rate is historically correct up to 1970. The assumption was that the usage would then begin to decline. (From: Meadows, D. H., et al. 1972. The Limits to Growth. Universe Books, New York).

biphenyls (PCB's) used in industry, do adversely affect hatchability of eggs in the domestic chicken. Scientists have shown that the chlorinated hydrocarbon pesticides may affect reproduction in at least two ways. Firstly, they induce the liver to produce steroid hydroxylase enzymes which alters the structure of steroid reproductive hormones. The hormones become more easily excreted: blood levels are thus lowered and reproductive behavior, such as delayed breeding, is affected. Also, these chemicals appear to inhibit the enzyme carbonic anhydrase which makes the supply of calcium carried in the bloodstream available to the oviduct where the eggshell is formed. Without the supply of calcium, a thinner eggshell results which is more fragile and thus susceptible to breakage.

Canadian biologists have shown that trout when exposed to DDT (20 ppb in the water) show inability to learn to avoid electric shock. Rats fed DDT following a learning experience took longer to relearn the maze--than did animals not so exposed. Estrogenic activity of DDT has been shown in rats and monkeys. DDT also induces steroid hydroxylating enzymes in the liver of the rat. The ultrastructure of liver cells in such animals show morphological changes that may be associated with altered function. Research in the cellular physiology laboratory at KSTC shows that DDT markedly affects the respiratory capacity of mouse and chicken liver mitochondria. In this case it appears that the mitochondrial membrane may be altered to produce this inhibitory effect.

There are some life processes that do not appear to be affected by these chemicals. DDT had no apparent effect upon aggressiveness in laboratory mice. In another study, DDT had no apparent adverse effects upon reproduction and lactation in the rat. A 15 week period of feeding DDT to turkeys did not cause alterations of blood pressure, gross structure of body tissues, histology of internal organs, or plasma levels of calcium, cholesterol and protein.

Human organophosphate exposure produced disorientation in space and time, a sense of depersonalization, and hallucinations. Heavy exposures produce convulsions. Electroencephalographic tracings (EEG's) implied abnormal activity in the temporal cortex of the brain.

The herbicide 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) has been shown to be teratogenic, that is, it induces fetal malformations in the golden hamster. The effects were less severe for the related herbicide, 2,4-D. Both of these herbicides have been used as defoliants during the Vietnam War. The United States government in 1970 imposed curbs on the usage of 2,4,5-T both for domestic purposes and as a defoliant in the combat zone.

The significance of pesticide contamination to human health is difficult to assess. For many pesticides such as parathion and dieldrin, the effects are rapid and distressingly final. However experiments have shown that chronic DDT intakes amounting to 1, 20, and 200 times the intake of the general population had no deleterious effects as shown by careful clinical follow-up and laboratory testing. Therefore it seems that any effects which might appear will be due to more subtle changes over a longer period of time.

New Approaches to Pest Control

Alternative methods of pest control are in many stages of development and several require more basic research before their potential can be evaluated.

1. **Resistant plants.** The outstanding example is the development of varieties of wheat resistant to the Hessian fly. Others now being used or developed include alfalfa for the spotted alfalfa aphid, leafhopper, and alfalfa weevil. Corn varieties have been released which are resistant to European corn borer, corn earworm, rice weevil and corn rootworm. The development, however, may take 10 to 15 years and in some areas such as cotton, progress has been particularly slow.

2. **Predators and parasites.** The first successful control program involved the importation of a ladybug, **Rodolia cardinalis**, from Australia for the control of cottony cushion scale, a pest of citrus in California. Ladybug beetles are a very beneficial group of insects and feed on aphids, scale insects and many other injurious species. The USDA feels that one of the most promising areas is the mass rearing of the lacewing larvae for control of bollworm. Praying mantids are completely predatory and feed on scale insects, aphids, various flying insects and caterpillars. The praying mantid will not attack the ladybug because of a scent given off by this beetle.

Parasites of injurious insects seem to have a great deal of potential for pest control. Parasites for the vector of Dutch elm disease and for the spotted alfalfa aphid have been discovered.

3. **Bacteria and viruses.** An insect pathogen which shows promise as a control agent is **Bacillus thuringiensis**. Perhaps even more promising are the toxins produced by this species. They appear to have a broad spectrum of activity but with little effect on higher animals.

Viruses have also been isolated which show promise for insect control. For example, a virus that is effective against the cotton bollworm (or corn earworm) is being developed.

4. **Sex attractants.** An approach that is receiving much emphasis is the development and use of insect attractants. These are natural compounds of insects which may be used to advantage such as attracting pests into traps. They may then be destroyed by other methods. Another use might be the spreading of the chemical which inevitably confuses the insect in its mating behavior. Potent attractants have been developed for the Mediterranean fruit fly, the melon fly and the gypsy moth.

5. Development hormones. Many scientists think that insect development hormones such as juvenile hormone, have potential in insect control. When present at certain stages of development they cause the formation of abnormal insects that cannot develop or reproduce.

6. The sterile male technique. The release of sterile male insects, made sterile either by chemicals or gamma radiation, has been a successful means of eliminating certain pest populations. Male insects are sterilized in such a way that their normal mating habits are not altered. Female mates of these sterilized males lay infertile eggs so offspring do not develop. This method has been particularly successful in controlling the screwworm fly population in the southern United States. The annual cost of this program is one-fifteenth of the estimated annual losses due to control costs and livestock damage before the insect was eliminated.

Future of Pesticides

Nonchemical methods of control are not expected to supplant entirely the use of chemical pesticides in the foreseeable future. It is imperative however that some of the practices be changed that have contributed to the erosion of environmental quality and public confidence. Dr. Robert L. Metcalf, Professor of Zoology at the University of Illinois, suggests that the sale be by prescription and the use supervised by trained plant pest control specialists or phytopharmacists. Professor Metcalf further suggests that successful pest management requires:

a. coordination of programs by highly trained specialists;

b. replacement of "routine" applications by applications based on an assessment of the problem;

c. recognition that some crops can tolerate substantial pest damage without economic loss;

d. abandonment of unnecessary pesticide treatments;

e. changes in agricultural practices to utilize selected crop varieties, cultivation practices, planting patterns, crop rotation, etc., to minimize the pest problem.

Suggestions for the Home Gardener

No panaceas are offered in this section which will allow the gardener to completely discontinue the use of pesticides. Most of the alternatives to chemical control discussed in a previous section are not practical for the backyard garden. As a matter of fact, it is my opinion that pesticides are still needed for use in the garden and on ornamental shrubs. However, ecologically oriented practices can minimize their use.

. Use gardening practices that aid beneficial species. Providing hiding sites such as lumber, stones and rank vegetation encourage these natural enemies to take up residence. Flowering weeds should be encouraged where they aren't overly competitive. Many beneficial species need a continual pollen source for protein from which to develop their eggs. Try collecting or buying beneficial species and releasing them in your garden. Green lacewings, praying mantids, ladybugs and others are all voracious predators.

Insect attack can sometimes be avoided by planting as early or late as possible. If the plant does not fit into the life cycle of the pest, a build-up of the population can be minimized. Furthermore, maintain as much diversity as possible. Monoculture (single-crop planting) usually encourages pest build-up. Avoid planting any crop in blocks. The following plants interspersed among the rest generally help repel harmful insects—mint, onion family, nasturtium and strong-smelling marigolds. Provide a water supply for birds and insects and nest boxes for insectivorous birds. Maintain organically rich soil.

If it becomes necessary to use pesticides, they should be used with extreme care. A discussion concerning some of the safer insecticides follows. A fuller explanation is given in the booklet Pesticides: A Guide to Safe Garden Use by Robert Dingwall.

1. Dormant oil spray. A three percent miscible oil dormant spray is effective against a variety of insect pests. Sucking and chewing insects such as aphids, red spiders, thrips, mealy bugs and others can be controlled. Eggs of codling moth, oriental fruit moth, leaf rollers and cankerworms can be destroyed by this method.

2. **Pyrethrum.** This compound is effective against a wide variety of insects and is probably the least toxic to man and higher animals.

3. **Rotenone.** This compound can be used safely on all crops and ornamentals. It has a very low toxicity to man and animals but the period of protection is short.

4. **Ryania.** This powder has little effect on warm-blooded animals but is useful in controlling cotton bollworm, codling moth, corn borers and other insects.

5. If stronger chemicals must be used, the following can be used with caution.

a. **Black Leaf 40** is a nicotine compound that is effective for sucking insects.

b. **Powdered sulfur** can be used for insect and fungus control.

c. **Sevin** is a carbamate with a short residual effect.

d. **Malathion** is the least toxic of the organophosphates to mammals.

e. **Methoxychlor** is the least toxic of the chlorinated hydrocarbons but is still quite potent and persistent.

Product List (Taken from The Living Garden, An Environmental Calendar, 1973)

1. **Oil Sprays**

dormant oil—such as Scalecide

summer oil—such as Ortho Volck, Sunoco Summer Oil

2. **Biological Controls**

Milky spore disease—a specific control for Japanese beetle grubs, available as "Doom" (Fairfax Biological Control Laboratory, Clinton Corners, N.Y. 12514). Preferably apply after ground thaws in early spring.

Bacillus thuringiensis—a bacterium which attacks only lepidopteran larvae, such as gypsy moth and diamondback moth larvae, tent caterpillars, tobacco bud and hornworms. Apply to specific pest caterpillars as they emerge. "Thuricide" (International Minerals & Chemical Corp., P.O. Box 192, Libertyville, Ill. 60048) or "Biotrol" (Thompson-Hayward Chemical Co., Box 2383, Kansas City, Kans. 66110).

Some beneficial predatory insects can be bought for release in the garden. They cannot be precisely managed, but the following will help control pests:

ladybugs—feed on aphids, scale insects, mealybugs, bollworms, leafworms, leafhoppers, corn earworms, etc.

praying mantids—feed on scale insects, aphids, caterpillars, etc.

Trichogramma—microscopic insect, harmless to humans, which lays its eggs inside those of butterflies and moths and destroys them. Repeated liberations can control codling moth, Oriental fruit moth and imported cabbageworm. (All three are available from Mincemoyer Nursery, County Line Road, Jackson, N.J. 08527; ladybugs and praying mantids from Montgomery Ward Farm Catalogue or Bio-Control, Rt. 2, Box 2397, Auburn, Calif. 95603; Trichogramma and praying mantids from Gothard, Inc., P.O. 370, Canutillo, Tex. 79835.)

3. **Botanical Sprays and Dusts**

pyrethrum—such as D-con House and Garden Spray, Raid House and Garden Spray, Ortho Home and Garden Insect Spray, Aerosect. Certain additives in pyrethrum sprays have possible hazardous side effects; avoid repeated exposure.

rotenone—available as spray or dust, such as Ortho Rotenone Spray and Dust; toxic to swine, very toxic to fish.

rotenone, ryania, pyrethrum—such as B.D. Tree Spray for orchards (Peter Escher, Threefold Farm, Spring Valley, N.Y. 10977; Tri-Excel DS, The Natural Development Co., Bainbridge, Pa. 17502).

nicotine sulfate—Black Leaf 40. Use with extreme caution, very toxic to humans; but like other botanicals, it breaks down into harmless compounds soon after application.

4. **Safer Fungicides**

Bordeaux mixture—copper sulfate and lime; can be toxic to fish and other aquatic organisms.

sulfur—may burn plants on hot, sunny days; apply in evening.

NOTE: Apply dusts and sprays with care and on a limited and identified target. READ AND FOLLOW DIRECTIONS. Apply when temperature is under 85 degrees or in evening to avoid damaging plants.

5. **Homemade Sprays for Aphid Control**

onion spray—grind or chop green onions, add equal amount of water, strain.

garlic spray—mix one part of garlic extract or powder with four parts water.

pepper spray—grind several capsules of hot pepper, add an equal amount of water, strain.

6. **Barrier Bands**

"Tree Tanglefoot" (The Tanglefoot Co., 314 Straight Avenue, S.W., Grand Rapids, Mich. 49500). Available as spray or wrapping material. Keeps webworm, gypsy moth and other caterpillars from reaching tree foliage.

7. **Other Sources**

W. Atlee Burpee Co., Box 6929, Philadelphia, Pa. 19132: compost maker, herb seeds, rotenone, "Tree Tanglefoot."

Geo. W. Park Seed Co., Greenwood, S.C. 29646: cover crop and herb seeds, rotenone, soil test kits.

Wayside Gardens, Mentor, Ohio 44060: Wayside Organic Plant Food, Sea-Born (dehydrated seaweed), Fertosan (organic compost maker).

Cosmic View, Inc., 4822 MacArthur Blvd. N.E., Washington, D.C. 20007: Cosmic Dust organic fertilizer.

8. **Birdhouses**

Audubon Bookshop, 1621 Wisconsin Ave., N.W., Washington, D.C. 20007: bluebird and other houses and building plans.

Trio Mfg. Co., Griggsville, Ill. 62340: martin houses—aluminum. Purple martins eat flies and mosquitos.

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The following are available at reasonable cost

Dingwall, Robert J. **Pesticides: A Guide to Safe Garden Use.** Missouri Botanical Garden, 2315 Tower Grove Ave., St. Louis, Mo. 63110, 75¢. **The Living Garden, An Environmental Calendar, 1973.** Available from Concern/ANS, 2233 Wisconsin Ave., N.W., Washington, D.C. 20007. $3.00 each or $2.50 each for orders of ten or more.

Bi. 536B. Workshop in Environmental Biology. 3 hrs. credit. Topeka area (Perry Reservoir), June 4-June 22. Persons enrolled will commute to the lakeside site for instructions in practical ecological concepts and techniques of environmental measurements. Particularly applicable for teachers. Request information from Dr. Robert Boles, Biology Department, KSTC.

Bi. 430. Workshop in Conservation. 3 hrs. credit. June 11-June 29. Seminars, lectures, discussions and field trips dealing with problems and status of natural resources. Especially desirable for teachers. Request information from Dr. Robert Parenti, Biology Department, KSTC.

High school seniors and students graduating from Junior Colleges who are interested in some field of science or in such fields as nursing, microbiology, and medically related areas are invited to visit the KSTC Biology and Physical Science Departments to look over the facilities, and to discuss the various programs with members of the staff. Science instructors and counselors are invited to bring groups of students with interests in science, and who might wish to take further training in this field. We suggest that you write or call in advance, so that someone may be provided to show you about the Science Department and introduce you to the faculty.

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